WINTHROP, STIMSON, PUTNAM & ROBERTS
1133 CONNECTICUT AVENUE, N.W.
WASHINGTON, DC 20036
TELEPHONE: 202-775-9800

TELEFAX: 202-833-8491
TELEX: 316229 WINSTIM DC

ONE BATTERY PARK PLAZA
NEW YORK, NY 10004-1490
TELEPHONE: 212-858-1000
TELEFAX: 212-858-1500

695 EAST MAIN STREET
STAMFORD, CT 06904-6760
TELEPHONE: 203-348-2300
TELEFAX: 203-965-8226

125 WORTH AVENUE
PALM BEACH, FL 33480
TELEPHONE: 407-655-7297
TELEFAX: 407-833-6726

2 THROGMORTON AVENUE
LONDON EC2N 2AP ENGLAND
TELEPHONE: 011-4471-628-4931
TELEFAX: 011-4471-638-0443

RUE DU TACITURNE 42
B-1040 BRUSSELS, BELGIUM
TELEPHONE: 011-322-230-1392
TELEFAX: 011-322-230-9288

17-2, NISHI-SHINBASHI 2-CHOME, MINATO-KU
TOKYO 105, JAPAN
TELEPHONE: 011-813-3437-9740
TELEFAX: 011-813-3437-9261

STANLEY M. GORINSON
202-775-9833

DOCKET FILE COPY ORIGINAL

DOCKET FILE COPY ORIGINAL

January 14, 1993

RECEIVED

JAN 14 1993

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

BY HAND

Rosalind K. Allen, Chief
Rules Branch
Land Mobile and Microwave Division
Private Radio Bureau
2025 M Street, N.W.
Room 5202
Washington, D.C. 20554

Re: RM No. 8013 - Old Crows' Comments

Dear Ms. Allen:

This will respond to your letter of December 9 requesting PacTel Teletrac to address the points raised in the late-filed comments of the Missile Group Old Crows.

Enclosed is a memorandum prepared by Yair Karmi, Vice President for Systems Engineering at PacTel Teletrac that refutes the points raised in these comments.

Should you require additional information, please let us know.

Sincerely yours,

Stanley M. Gorinson

Stanley M. Gorinson

cc: Ralph Haller
Beverly Baker
Kent Nakamura
Ronald Netro
Parties of Record

No. of Copies rec'd 0+5
List A B C D E

#60015851.1

RECEIVED

JAN 1 4 1993

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C.

In the Matter of	)	
	)	
Amendment of Section 90.239 of the	)	RM No. 8013
Commission's Rules to Adopt Permanent	)	
Regulations for Automatic Vehicle	)	
Monitoring Systems	)	

TO: THE COMMISSION

RESPONSE OF NORTH AMERICAN TELETRAC AND LOCATION TECHNOLOGIES dba PACTEL TELETRAC TO THE COMMENTS OF THE MISSILE GROUP OLD CROWS

Prepared By

Yair Karmi
Vice President for Systems Engineering
PacTel Teletrac

January 14, 1993

RECEIVED

JAN 14 1993

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

In response to the comments of the Missile Group Old Crows ("Missile Group"), filed late in RM No. 8013, and as requested by letter dated December 9, 1992 from Rosalind K. Allen, Chief, Rules Branch, Land Mobile and Microwave Services, Federal Communications Commission, North American Teletrac and Location Technologies, Inc. through their joint venture PacTel Teletrac ("Teletrac"), submits the following information.[1] The Missile Group raises a number of technical questions concerning the Petition for Rulemaking (RM No. 8013) filed by Teletrac on May 26, 1992. In particular, the Missile Group alleges that Teletrac's Automatic Vehicle Monitoring ("AVM") system contains various "design defects" that could easily be rectified "without exclusivity and with a better technical approach." (Missile Group Comments, p. 2).

I. Discussion

A. Background to Teletrac

Teletrac came about because its founder, Dennis Kahan, became concerned that, in our society, children could too easily become lost or kidnapped.[2] From that concern, a technology was created that currently permits users to locate vehicles instantly, thereby reducing car thefts and carjackings, and soon will be capable of locating children and other persons.

Mr. Kahan and his partner Mark Licht met with a team of design engineers, including spread spectrum pioneer Robert Dixon, in 1984. The engineers were asked to design a system that could locate children and other people, as well as objects such as vehicles. Any solution, in order to be commercially successful, had to be accurate and low cost so that it would attract a wide range of consumers.

The Teletrac technology that emerged from the design team's efforts is based on direct sequence (pseudo-noise based) spread spectrum techniques originally developed by the military to improve the ranging accuracy of aircraft.[3] The technology applies those techniques to terrestrial ranging problems, permitting accurate, low cost, automated monitoring of objects.

---

1. The Missile Group filed its reply comments after the due date and after Teletrac had filed its Response to the Comments received within the proper timeframe.

2. The Teletrac System was created because of Mr. Kahan's feelings that technology must be developed to protect children after seeing the TV movie "Adam," depicting the kidnapping of a child who was never recovered.

3. R. A. Scholtz, "The Origins of Spread Spectrum Communications", *IEEE Transactions on Communications*, vol. COM-30, p. 822, May 1982.

B. Technology Development

By 1986, Teletrac had completed an initial prototype system and by 1988, the system could locate vehicles with very high precision. However, the technology used in that second generation system could still not support a high coverage, high capacity system that would make service affordable and attractive to a broad customer base. Thus, additional research and development was necessary to "marry" state of the art VLSI technology and military data link spread spectrum technology to achieve a commercially viable location system. This development effort lead to time of arrival (TOA) processors with performance close to the theoretical bounds. Teletrac also adopted a licensing policy allowing any vendor to manufacture a radiolocation unit (RLU) compatible with the system. Since 1987, seven companies have been licensed to manufacture and distribute units compatible with the Teletrac system -- Audiovox, Codealarm, Kenwood Corporation, Matsushita Electric Works, Mitsubishi International Corporation, Samsung Electronics, and Tadiran Ltd. These companies currently manufacture units about the size of a VHS video tape. Research and development is proceeding, however, to miniaturize these units further.

Development of the initial prototype system provided the proof that a land-based radiolocation service, capable of operating in the urban environment where satellites are often out of sight, is feasible. However, extensive R&D as well as other investments involving tens of millions of dollars were still required to turn the system into a commercial reality. To achieve this goal, the original developers joined forces with PacTel Corporation, a subsidiary of Pacific Telesis Group, to commercialize and deploy the second and third (present) generations of the system. Teletrac systems are now in commercial operation in Los Angeles, Chicago, Detroit, Dallas, Miami, and Houston.

C. Teletrac System Design and Major Components

1. The Design and Components

Teletrac's network is composed of transmit and receive sites connected to a central computer and operations facility (the Network Control Center). The network enables authorized users to locate a properly equipped vehicle within 100 feet and display that vehicle's location on a computer terminal. Subscribers install inexpensive RLUs and authorized dispatchers, managing either commercial fleets or operating in law enforcement agencies, use a workstation and modem or a standard telephone to locate vehicles. The network is constructed, maintained, and operated by Teletrac to support multiple users on a subscription basis. Teletrac services include Corporate Vehicle Locator Service, Stolen Vehicle Locator Service, and Emergency Alert or Panic Service.

The system uses specialized fixed transmitters and receive sites installed in strategic locations throughout the metropolitan coverage area. Each system is designed to have redundancy in tower deployment to minimize the possibility of system failure due to the loss of one or several receive sites. The receive sites gather signals from RLUs installed in vehicles as well as from the fixed transmitters. They measure the TOA of each signal and route the data to the Network Control Center (NCC), where signals from all receive sites are further processed to determine actual vehicle location.

To maximize the coverage area of the system, receive sites are placed at high elevation locations for maximum signal visibility. Given the conditions of the urban environment, and because the location computation is based on one-way TOA measurements, TOAs from a minimum of four receive sites are required to compute a vehicle's location. However, signals received by this number of sites do not support acceptable accuracy due to the errors caused by multipath.[4/] Additional redundancy is required to identify erroneous ranging measurements and provide an accurate solution. The use of additional towers also reduces the negative effects of geometric dilution of precision (GDOP)[5/] so that vehicles far away from the center of the coverage area are located accurately.

The Network Control Center consists of a group of networked computers that make up the information processing hub of the system. The basic functions of the Control Center include interrogation of RLUs, processing of responses and data channel processing. The TOA measurement from the receive sites are processed to compute the vehicle's location.

Fleet vehicles to be monitored by the Teletrac Corporate Vehicle Locator Service are equipped with RLUs. The RLUs are manufactured to Teletrac specifications by licensed vendors. These units are compact (typical dimensions are 6 inches long, 4 inches wide, and 1.5 inches high) and are designed for reliable operation in a mobile environment. The cost of these units is declining rapidly as the demand increases and manufacturing experience leads to more efficient manufacturing technology. Teletrac offers several different antenna configurations to accommodate a wide range of vehicle types. Antenna configurations range from a cellular-type 3 dB gain antenna to a hidden antenna (-3 to -12 dB gain). All antennas are designed for operation in the 900 MHz range.

---

4. Multipath errors are caused when the signals received from the RLUs take indirect paths, causing the measured TOA to be longer than the direct or line of sight path. The subject of multipath is discussed infra at subsection C.2.

5. Geometric dilution of precision (GDOP) occurs when the location of the receivers relative to the vehicle cause the estimation of the location of the vehicle to be especially sensitive to small errors in the measurement of the pulse TOAs.

An emergency "panic" button is also available. When depressed, the panic button transmits an emergency message that is received at the NCC. This message is also automatically passed through to the subscriber's computer workstation. The emergency message identifies the vehicle and provides the vehicle's location.

The workstation used by fleet or law enforcement customers is an IBM compatible computer (386 or 486) with VGA monitor and internal modem. The Vehicle Location System user software is supplied with the workstation. The workstation is used by the dispatcher or fleet manager to request and view the location of fleet vehicles on a computer map display and in tabular form. A direct computer interface is also available to allow access to Teletrac system services by Computer Aided Dispatch systems used by large commercial and transit district fleets.

2. System Operation

The NCC controls all of the communications between the transmit and receive sites and provides vehicle location information to system subscribers. The NCC is staffed by trained operators who monitor system operation 24 hours a day, 365 days a year. For the Stolen Vehicle Service, Teletrac NCC operators contact the appropriate law enforcement officials when a Teletrac-equipped vehicle is stolen, providing stolen vehicle identification and location information over the telephone or by computer. Unless required by emergency conditions, commercial fleets are monitored by their dispatchers, bypassing the NCC operators.

Requests to locate vehicles are made using the subscriber's computer workstation. These requests may be sent to the Network Control Center by manual request or automatically at pre-set intervals. The user may choose to update the location of all fleet vehicles, a portion of the fleet, or a single vehicle.

The location request is passed over standard telephone lines (dial-up or leased) to the Network Control Center and is immediately forwarded over telephone lines to the fixed transmitters which interrogate the selected vehicle. Upon receipt of its address, the RLU transmits a pseudo-noise (PN) pulse.

The PN pulse is received by multiple receive sites and TOA measurements are performed. The TOA measurements are reported to a high speed computer in the Network Control Center that calculates the location of the RLU in NAD 83 coordinates. The resulting location is then converted to NAD 27 coordinates and forwarded over standard phone lines to the subscriber's workstation. The system is currently capable of 35 location transactions per second and will be increased to 70 location transactions per second in the near future.

C. Other Considerations

1. Spread Spectrum Communications Systems

Spread spectrum techniques are typically applied in systems needing either secure anti-jam communications or very accurate timing or ranging. As with the design of any complex system, there are trade-offs that must be made between all performance parameters. Typically, the primary performance requirement of a spread spectrum communications system is to pass data from one point to another with high reliability in an environment with jamming or interference . If overcoming jamming or interference were the only requirement, then the system designer might increase the power of the transmission in an attempt to overcome the interference. However, other requirements such as having a low probability of interception, equipment cost, available spectrum bandwidth, and power source constraints prevent this simple solution.

Thus, all communications systems are design trade-offs, based on operational requirements and regulatory constraints. For example, if the primary goal is to engage in voice and data communication, then other information that a spread spectrum system can provide (such as accurate range measurement) may not be used or might even be sacrificed so that additional data can be sent.

An example of this trade-off is a proposed CDMA cellular telephone system design. This system sends digitized voice data at rates up to 9600 bits per second using a PN chip rate of about 1.2 MHz. It appears that the design includes the use of a rake receiver to take advantage of receiving and combining multiple signals caused by multipath to increase the probability of receiving data correctly.[6] However, this type of receiver is not optimized for timing and range information. In addition, the power is limited to enhance communications capacity by overlaying multiple simultaneous transmissions from different mobile units rather than by supporting reception of one transmission from a single unit to multiple sites. Because the primary use of the CDMA telephone is to transmit data and not to make accurate range measurements, this is the correct performance trade.

When implemented, this CDMA telephone system would occupy 1.25 MHz of spectrum. To achieve maximum capacity, the system is designed for exclusive band occupancy and assumes no continuous wave (CW) interference in its receiver passband.

Location systems using spread spectrum technology typically pass little if any data between users, but instead use the PN coding to very accurately measure the time of arrival of the received signal. For example, the GPS system transmits data at the

---

6. See, e.g., *An Overview of the Application of Code Division Multiple Access (CDMA) to Digital Cellular Systems and Personal Cellular Networks*, QUALCOM Incorporated, Document Number EX60-10010, May 21, 1992, p. 10.

extremely low rate of about 50 bits per second while using either a chip rate of either 10.23 MHz for precision positioning service (military) users or 1.023 MHz for standard positioning service (civilian) applications.

This difference of almost 200 times in data rates between the CDMA cellular telephone and the GPS system applications of spread spectrum technology (even at the same chip rate) shows the contrast between the requirements of data transmission and location determination. Other differences include the type of modulation and its influence on time accuracy and the performance impact of multipath. In both cases, however, the systems discussed above (the CDMA Cellular Telephone and GPS systems) use an exclusive band to achieve their designed levels of performance.

2. Effect of Multipath on Ranging Systems

Multipath is a major degrading factor in the performance of radiolocation systems. Accurate ranging information is only available in the earliest arriving signal (as opposed to signals delayed by multipath). Different versions of the same signal arrive at the receiver with increasing delays, because they travel longer paths. Typically, signals arriving with a delay of more than 1 chip time may be separated from the earliest arriving signal based on the autocorrelation function of the PN spreading sequence. This is not always possible when the multipath signal is much stronger than the earliest arriving signal. Multipath that is delayed less than 1 chip time biases the result of the correlation, causing errors in the TOA measurement that make the measurement either earlier or later than the true time.

The accuracy of the resulting TOA measurement is a direct function of the signal to noise ratio and the noise characteristics at the receiver. In the absence of other interfering signals, however, the advanced digital signal processing technology used in the Teletrac TOA processor can characterize signal distortions caused by multipath and improve the estimate of the TOA of the received signal. However, in an environment with constantly changing interference characteristics, this is not possible and leads to errors in the TOA measurement.

Experiments have shown that the delay spread of arriving signals can average more than 4 microseconds and be greater than 10 microseconds.[7/] These data also show that although the receive signal level of multipath signals delayed more than 2 microseconds is typically 15 to 20 dB lower than the earliest arriving signal, they can occasionally be at the same or even at a higher power level.

---

7. D. Parsons, *The Mobile Radio Propagation Channel*, John Wiley & Sons, 1992, p. 236.

Ranging systems are typically designed to compute range on the first arriving signal. After the first signal arrives at the receiver, all other versions of the signal arriving at later times take a longer path (i.e. more bounces) to get to the receiver, and typically arrive at lower power levels. While ranging systems attempt to receive the first signal, the other signals arriving tend to interfere with the process of receiving the first signal decreasing the accuracy of the TOA measurement. Thus, while systems such as the CDMA cellular telephone can take advantage of the multipath signals, the performance of ranging systems is degraded by multipath.

3. Signal Modulation and Other Differences

Another area of difference between communication and ranging systems is the type of signal modulation.[8/] Communications systems are usually designed to maximize the information sent in a given bandwidth and thus typically use special modulation techniques such as Minimum Shift Keying (MSK) to minimize spectrum utilization. Ranging systems, like Teletrac, are designed to maximize the accuracy of the time (and therefore the range) measurement and may use modulation techniques which maximize the *effective bandwidth* of the signal.

The concept that the effective bandwidth of different modulation schemes produces different time-delay or range measurement accuracy is well covered by M. Skolnik in *Introduction to Radar Systems*. He states, "[t]he radar waveform which yields the most accurate time-delay measurement, all other factors being equal, is the one with the largest effective bandwidth." He then shows the difference in time delay measurement accuracy caused by different pulse modulation schemes such as rectangular pulses (in effect bi-phase modulation) and gaussian pulses (gaussian MSK). The results show that the accuracy attainable for a given bandwidth and transmission time (chip rate), with bi-phase modulation is more than twice that of MSK.[9/]

The accuracy of the TOA measurement is also affected by the received signal to noise ratio at each of the sites which receives the signal. Location/ranging systems like Teletrac require simultaneous high quality measurements to be made over three or more transmission paths in order to compute an accurate location. In contrast, communications systems such as the CDMA cellular system only need to communicate using a single transmission path (a single cell site). In fact, in order to increase cellular capacity, cellular systems actively adjust and reduce the transmission power from mobile units so that the link closes with very little margin. This type of power control is

---

8. Again, we are using the phrase "communications system" to refer to systems optimized for information transfer (maximum bits per second) as opposed to "ranging systems" to refer to systems optimized for location estimation (maximum number of accurate locations per second).

9. M. Skolnik, *Introduction to Radar Systems*, McGraw-Hill, 1980, p. 407.

impractical in a location system because of the requirement that the signal be received at multiple sites so that its location can be determined. In general, the more sites that receive the signal, the better the accuracy of the computed location.

Thus, the requirements for communications systems and location/ranging systems which utilize spread spectrum techniques, are driven by vastly different and mutually exclusive requirements for bandwidth and information content. However, the goal of both types of systems is to maximize the number of customers served for a given spectral bandwidth at some minimum level of service (data throughput, voice quality, or location accuracy).

4. Satellite v. Terrestrial Ranging

Numerous studies and field tests have shown that GPS receivers, which must track at least 3 satellites to even get a two-dimensional location (4 satellites are required for 3D locations), are prone to blockage by buildings and foliage when used in cities. In tests in rural areas of Canada, "the actual coverage was significantly less [than predicted] due to masking effects caused by the topography and trees."[10/] In those tests, coverage was as low as 25% but typically varied from 45 to 95%. Thus, even in rural areas, satellite blockage can be a significant problem.

In urban areas, however, the key requirement for AVL systems that are GPS based is to minimize the effects of satellite blockage. This is a severe problem because line of site may be blocked to 3 or more of the available satellites.[11/] A study which modeled this blocking showed that in a suburban or city environment, where the satellites are masked below 65 degrees on each side of the street by buildings or trees but with visibility down to 10 degrees ahead and behind, a GPS receiver will be able to track 3 or more satellites only about 80 percent of the time (4 or more only 45%). As the building height increases (blockage up to 75 degrees) as in a downtown area, the receiver can track 3 or more satellites only 70 percent of the time (4 or more only 30%).[12/]

This poor coverage in urban areas occurs because the link margin in the GPS system is stretched to the limit. The GPS satellite transmits with an effective radiated power of 25 to 28 dBW depending on elevation. The path loss from the satellite at an

---

10. G. Lachapelle, B. Townsend, D. Halayko, "Analysis of GPS and Loran-C Performance for Land Vehicle Navigation in the Canadian Rockies," IEEE 1992 Position Location and Navigation Conference Record, pp. 504-508.

11. M. Rothblatt, "The First GPS Satellite Radio Optimized for Automatic Vehicle Location," IEEE 1992 Position Location and Navigation Conference Record, pp. 524-527.

12. A. Brown, "A Low Cost Vehicle Tracking System," IEEE 1992 Position Location and Navigation Conference Record, p. 521.

altitude of 11,000 miles to a receiver on the earth's surface is 182 to 184 dB leaving a receive signal level of -155 to -160 dBW.[13] To solve this problem, most GPS-based vehicle navigation systems include a separate back-up dead reckoning system to supply locations in areas where the GPS receiver is blocked by buildings or foliage.

The limited link margin of a GPS based system also eliminates its use in the consumer stolen vehicle recovery market. GPS systems require an antenna with a minimum gain of 0 dB. Thus, there is no possibility of hiding an antenna without significant vehicle body modifications. Since the antenna would most likely be exposed, a GPS based system could easily be defeated by a car-jacker or thief. Even if unnoticed by the thief, a vehicle which was parked in a garage or parking structure or even under dense tree cover could not receive any signals from the satellites because of the excess path loss. This makes GPS or other satellite systems impractical for this consumer application.

Because of the shorter distances involved with a terrestrially based location system, the Teletrac system is designed to provide 99% coverage within the metro area, without the need for any auxiliary navigation equipment in the vehicle. The signal level of Teletrac allows the use of standard omni-directional antennas, and even antennas that are hidden in the vehicle. This reduces the cost to the customer below any GPS-based competitive solution.

To achieve accurate locations when using GPS in the standard positioning service (SPS), in addition to the receiver/satellite line-of-sight requirement, some type of differential GPS technique may be required to meet the typical desired accuracy of 100 feet. This is due to the fact that the US Department of Defense has implemented Selective Availability (SA) which causes errors of up to 100 meters (2DRMS) in the locations calculated from SPS data. In addition, errors can be magnified by the effect of geometry of the satellites or the Geometric Dilution of Precision (GDOP). The GDOP or Position Dilution of Precision (PDOP)[14] for the GPS constellation under good conditions is 4 to 6.

The Teletrac system, like any ranging location system, is also sensitive to the effects of GDOP. To overcome this problem, the Teletrac network is designed with additional receive sites to minimize GDOP. Because multiple sites receive the signal, the solution can be computed from selected sites with the least GDOP. This is one reason why it is important for the location transmissions to be received at numerous, geographically diverse sites.

---

13. B. Forssell, *Radio Navigation Systems*, Prentice Hall International, 1991, p. 277.

14. PDOP (position dilution of precision) describes a concept similar to GDOP, <u>see</u> note 5, <u>supra</u>. The term PDOP, however, frequently is used with respect to satellite navigation systems.

Unfortunately, the sites with better GDOP tend to be those located furthest away from the transmitter. The received signal levels at sites far away from the transmitter may be well below the local noise floor. However, for good GDOP, it is important that these sites receive the signal and provide additional TOA information thereby improving the overall accuracy of the calculated location. Any interference that exceeds the local noise floor level by greater than the processing gain will corrupt the received signal and cause errors in the TOA measurement.

5. Advantages of the Teletrac System

Teletrac develops location information in the fixed system instead of the vehicle as with Loran-C and GPS based systems. This gives the Teletrac system some distinct advantages for certain customer applications. First, the RLU sends the location signal to a central point, so there is no need for additional communications links. These links are a common requirement in Loran-C and GPS based systems. Second, these are no complicated interfaces to two-way radios or other communication links. Thus, the Teletrac system is much easier to integrate into a customer's operation. Third, Teletrac systems use simple 900 MHz antennas and the system has sufficient signaling margin to allow easy implementation of hidden, or under-cover operations applications. Loran-C systems (low frequency antenna) or GPS systems (high frequency dish antenna) are not well suited for these applications. Fourth, line of sight propagation is seldom blocked because of the large number of fixed receiver antennas, providing a type of space diversity. The user receives location data when paths are blocked, but at a reduced accuracy.

II. Responses to the Missile Group Old Crows Letter

A. General Comments

The Missile Group Old Crows (Missile Group) comments simply have no basis in fact. Indeed, no references or authorities were provided to support these comments. In our view, the comments seem to lack a basic understanding of radiolocation technology.

In the previous section, the differences in the requirements and design parameters between spread spectrum communications systems and radiolocation systems were presented. It appears that, while the Missile Group may have knowledge in the design of some communications systems, it has very limited experience with the use of spread spectrum techniques for radiolocation and is unacquainted with the application of modern digital signal processing techniques to spread spectrum systems.

B. Specific Comments

Page 1:[15] *Most of our members use high gain antenna arrays, and many have frequency agility throughout the 902-928 MHz band. As such, the Arlington, Texas engineering staff of PacTel Teletrac has called on our members on several occasions to locate sources of interference.*

Response: The Dallas office of Teletrac has never requested the Missile Group's help in locating sources of interference. The initial contact between Teletrac and Mr. Britain, who signed the comments on behalf of the Missile Group, was initiated by Mr. Britain. He called the Dallas Teletrac office and introduced himself as the president of a local HAM club. He invited Marvin Fath, the Teletrac Field Engineering Supervisor to speak at a club meeting. At that meeting, Mr. Fath discussed only how the system works conceptually. Mr. Britain was also given a tour of the NCC, but at no time was he given any technical data - as is obvious from some of the erroneous technical assumptions made in the Missile Group's comments. Teletrac's Dallas metro operations have not noticed any interference caused by HAMs in the area.

Page 2: *"Design Defect #1: Wide VCO Bandwidth"*

Response: The Missile Group appears to be unaware of the modern spread spectrum technology used in the Teletrac system. The technique described in the Missile Group reply comment of phase locking a voltage controlled oscillator (VCO) at four times the center frequency of the received signal is the classical solution for spread spectrum communications described in the literature as a Squaring Loop.[16] No modern spread spectrum system uses such a low performance technique for demodulation because of its sensitivity to CW interference. This sensitivity is caused by the use of amplitude demodulation for the AGC in such applications, causing the VCO to loose lock when CW interference is received near the center frequency.

---

15. The Missile Group has not numbered the pages or paragraphs of their comments. Thus, we assigned numbers to the pages ourselves. Page 1 is the first page of their comments.

16. R. Dixon, *Spread Spectrum Systems*, John Wiley & Sons, 1984, pp. 191-192.

Page 2: *"Design Defect #2: Detection using simple DC coupled Low Pass Filter"*

Response: The use of simple AC coupling filters out DC voltages. Therefore, the only CW signal that may be filtered out using this technique is a signal that converts to a DC voltage (i.e. is at the center frequency). Simply "adding a few capacitors" will only affect CW interference that is exactly at the center frequency of the receiver baseband. It does not contribute at all to the rejection of multiple CW carriers.

Integrate and dump is a data demodulation technique usually used in the implementation of communication receivers designed to yield maximum performance in the presence of white gaussian noise. This type of solution is not applicable to radiolocation receivers since it destroys the phase dependent TOA information within the chips, leading to only a 1 chip resolution (hundreds of nanoseconds) that is unacceptable for radiolocation system performance. As explained above, the implementation of the Teletrac TOA receivers yield measurement performance close to the theoretical bounds.

Page 3: *The PacTel Teletrac system uses only 3.2 MHz of the 8 MHz allocation. To guard their fragile receivers, they need as much guard frequency as could hold 1600 Analog Cellular Telephone Channels.*

Response: As stated previously, the Teletrac system is a radiolocation system which is based on ranging. The requirements for such a system are significantly different from those of a spread spectrum voice communications system in several areas. Ranging systems are designed to provide the most accurate timing measurement for a given transmission length and bandwidth. They utilize modulation techniques that provide high time measurement accuracy. Such modulation techniques may not be the most spectrally efficient when used for data communications but are chosen based on their *effective bandwidth*.

At this stage in the development process, the Teletrac system uses the center 4 MHz of the 8 MHz band. The remaining 4 MHz is not a guard band. Rather it is intended to be used as the number of subscribers increases and new services are introduced. Substantial increases in demand as market penetration increases will necessitate additional spectrum even if no new services are introduced. The personal locator service originally envisioned by Teletrac's founders, which Teletrac hopes to deploy in the near future, also requires additional spectrum. A location device small enough to carry must transmit a longer duration signal over a wider bandwidth (up to 8 MHz) to compensate for the power limitations and antenna inefficiencies inherent in a battery powered hand held device. However, even though the personal locator may use the entire 8 MHz band, there will be no need for a frequency guard band. The sharing of the spectrum by both the personal and vehicle locator signals is made possible by means of common system timing, synchronization and control, thus reducing the mutual interference to the level where radiolocation accuracy is acceptable.

Note that the Missile Group alleges in its comments that the 4.8 MHz guard band will hold 1600 analog cellular channels. In fact, since each analog cellular user requires two 30 kHz simplex channels, for a total of 60 kHz, the 4.8 MHz could (in theory) support only 80 cellular channels.

Page 3: *This very poor spectrum use impacts the Secondary and Part 15 users.*

Response: Based on the discussion in the response to the previous statement and the technical data provided in the previous section, we believe that the Teletrac system makes excellent utilization of the spectrum it occupies. Moreover, Teletrac has not experienced any substantial difficulties with Secondary and Part 15 users.

Page 3: *PacTel Teletrac and the public would be better served by upgrading or fixing their cell site receivers as soon as possible.*

Response: Teletrac's receiver technology is state-of-the-art. It is based on advanced digital signal processing techniques and its performance is very close to the theoretical limits.

Page 3: *Properly designed Spread Spectrum Systems operate with dozens of CW carriers within the receiver passband.*

Response: As previously stated, spread spectrum communications systems operate in a significantly different manner than a high capacity location and ranging system. Despite the need to close the RF link at only a single site, the CDMA cellular system, as well as other commercial spread spectrum communications systems, use an exclusive band, free from CW interference, to operate efficiently. In contrast, signals used in location systems must be received at a minimum of 4 sites - with additional sites required to achieve high accuracy in the computed location. Teletrac's system performs these functions today within the hierarchy of use governing this band.

Any CW carriers above noise floor will degrade the radiolocation accuracy, independent of the processing gain. The received signal levels at sites far away from the transmitter may be well below the local noise floor. However, it is important for these sites to receive the signal for good GDOP, and to provide additional TOA information to improve the overall accuracy of the calculated location under the multipath conditions characteristic of the urban environment. For signals received near the system sensitivity threshold, large errors in the TOA measurement will occur. This is true for any radiolocation system, commercial or military.

Page 3: *This is a prime example of an area where military technology spin-offs (Adaptive Suppression) can be applied to commercial system.*

Response: Adaptive techniques such as steerable null antennas, which have been used in military systems for a long time, have been considered for use in the Teletrac system for combating interference.[17/] However, their use requires multiple antennas at the receive sites. The antenna pattern creates blind spots degrading service to customers. The cancellation available from such devices is also limited to 30 to 40 dB in the absence of multipath. In the typical urban environment where signals bounce off vehicles and the power of variable multipath reflections is close to the direct signal, the performance available from such devices is significantly inferior. As a practical matter, implementation of interference suppression techniques may yield only an improvement of about 10 dB, at the expense of distortion to the TOA information.[18/]

---

17. "Impact of Co-Channel Interference on 900 MHz Wideband AVM System Performance", Appendix 2 of the Petition for Rulemaking filed by North American Teletrac and Location Technologies, Inc., pp. 18, 20, May 26, 1992.

18. Prof. L. B. Milstein, "Interference Rejection Techniques in Spread Spectrum Communications," Proceedings of the IEEE, vol. 76, no. 6, June 1988.

Conclusion

For the reasons stated above, Teletrac believes the Missile Group substantially misunderstands Teletrac's technology and its application to the solution of location problems. The Commission, therefore, should disregard those comments.

Respectfully submitted,

Yair Karmi
Vice President - Systems Engineering
PacTel Teletrac

January 14, 1993